Targets developed in the 21-st century at the P.N. Lebedev physical institute of RAS to study the extreme matter Physics using high-power laser facilities

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ABSTRACT

- We report developing thermonuclear laser targets in the P.N. Lebedev Physical Institute of the RAS for fs to 100-ns high-power and/or high-energy lasers.
- The new targets were also supplied for experiments with lasers and heavy-ion driver and for powerful electro-physical installations for the sake of controlled fusion studies.
- Cryogenic setup for to form and deliver to the interaction zone the fuel thermonuclear targets was developed, constructed, produced and tested.
- All the targets worked successfully for extreme matter plasma experiments, astrophysical modelling, “accelerators on the table” and different interdisciplinary application fields.

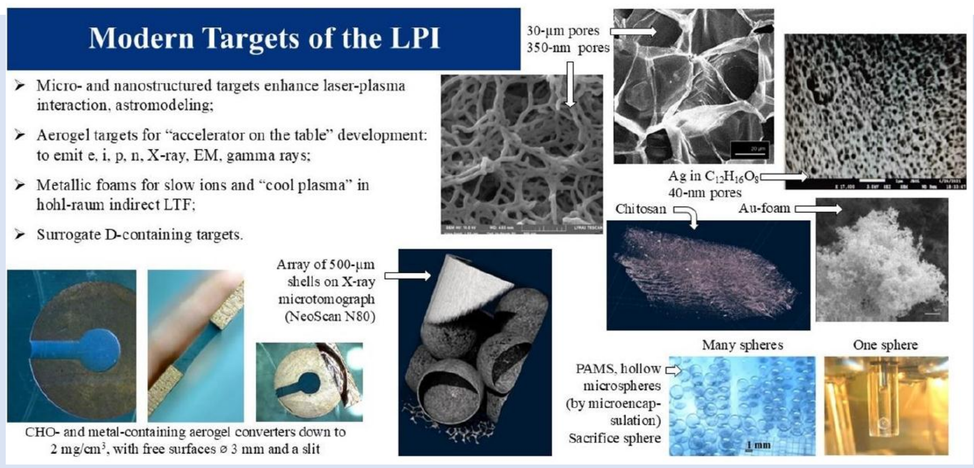


Fig.1. Modern targets of the LPI RAS, used in research on various lasers

BACKGROUND

We are now 60 years apart from the time when the idea of Laser Thermo-nuclear Fusion (LTF) was proposed by N.G. Basov and O.N. Krokhin [1]. What is the mission of targets now in the era when experiments have demonstrated several-fold thermonuclear energy yield under NIF irradiation of target? The mission is still to provide the diversity of investigations regarding physics of the extreme matter states in each laser available from the unique Facilities developed in the framework of national programs to the Universities’ less scale (energy and cost) installations with its definite parameters, resources, limitations.

The original targets and equipment were worked out in the community of Russian institutes. The shot experiments provide the new phenomena from novel targets and verify the requirements for the further target works, which sometimes become orders of magnitude easier than the initial theoretic demands.

METHODS

TARGETS

Spherical shells for fuel thermonuclear research, H2-containers, sacrifice shells; Low-density plastic air-gels and metal foams as research targets; metallic foams

METHODS FOR TARGETS RESEARCH

We using SEM, X-ray microtomography (Neoscan N-80),
Syncrotron microtomography (PETRA-III)

CRYOGENIC SETUP

LPI designed, created the setup for actual facility, and is ready to make a series of setups (to be replaced after several full-energy shots) see fig. 2. The shields are simulated and designed so that liquid He is not fully evaporated after shot and thermonuclear microexplosion of the DT-target [8]. The constructions can be modified for other installations and facilities.

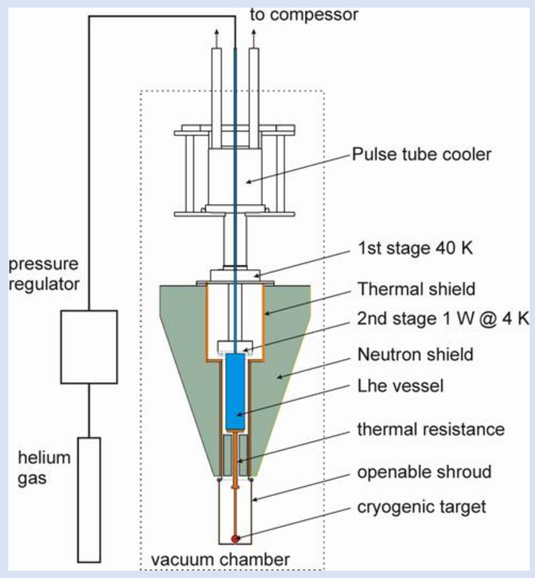
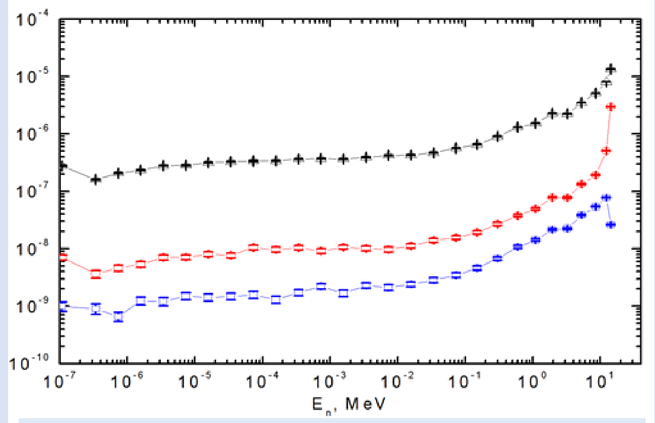


Fig.2. Cryogenic setup for laser targets.



The energy dependency of neutron flux at liquid He vessel bottom (black), at 1-st stage of the cooler (red) and on neutron shield top at its half radius (blue).

In this curves flux normalized by total neutron flux F0 irradiated from target in 4π per one laser pulse.

Fig.3. The neutron flux reduction.

OUTCOME

Thermonuclear targets for neutron and no-neutron fusion were performed in laser experiments

- **Innovate**: Aerogel targets and metallic foams were developed.
- **Partner:** Mobilize partnerships to further explore the generated ideas and support the needs identified in the Department’s R&D PlanThe joint laser experiments within the programs DST-RFBR, FAIR, HiPER, National Center for Physics and Mathematics, European experiments within LaserLab Proposals, on such Facilities as LULI, PALS, LIL
- Many Russian institutes and enterprises worked in collaboration for target research

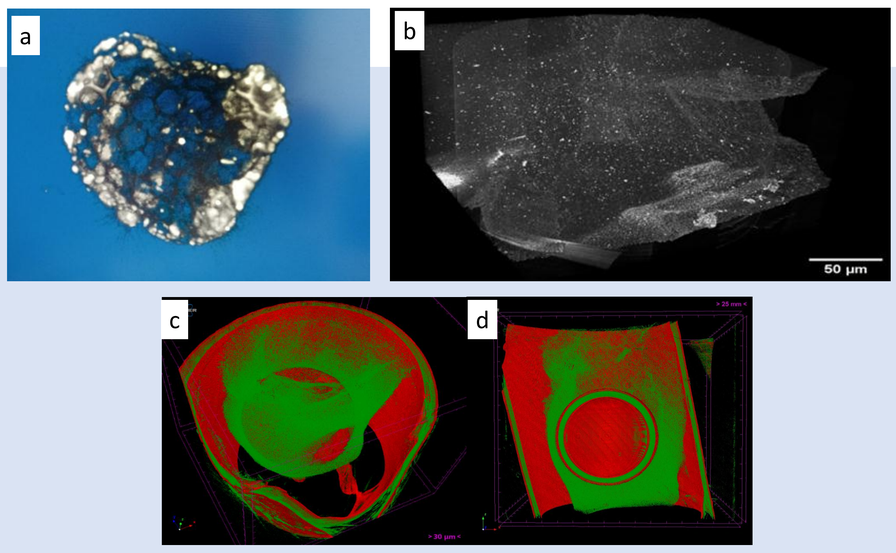


Fig.4. X-ray (a) and syncrotron (b-d) microtomography of metalic clusters in plastic aerogel

CONCLUSION

- New termonuclear targets based on plastic microspheres, micro- and nanshell, aerogel and metallic foams for femtosecond laser were developed.
- Cryogenic setup for target were constructed
- Well-organized target works allow for minimum time from hypothesis to the laser irradiation experiments. This makes the relevant scientific field “targets for LTF” attractive and very important.

REFERENCES

[1] Basov, N.G., Krokhin, O.N., JETP **46** 1 (1964) 171-175.
[2] Gyrdymov, M., Cikhardt, J., Tavana, P. et. al., Sci Reports **14** 1 (2024) 14785.
[3] Cikhardt, J., Gyrdymov, M., Zahter, S. et. al., Matter Radiat. Extremes **9** 2 (2024) 027201.
[4] Pastukhov, A.V., Mat. Today Comm. **39** (2024) 109043.
[5] Pastukhov, A.V., Pervakov, K.S., Akunets, A.A. et. al., J. Appl. Polymer Sci. **139** 41 (2022) E52997.
[6] Artyukov, I., Borisenko, N., Burenkov, G. et. al., Photonics **10** 8 (2023) 875.
[7] Borisenko, N.G., Akunets, A.A., Borisenko, L.A. et. al., JPCS **1692** 1 (2020) 012026.
[8] Rybakov, A.S., Demikhov, E.I., Kostrov, E.A. et. al., Laser and Particle Beams **37** 1 (2019) 24-29.